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DESCRIPTION

# Method of Grouting Internal Cable of Post-Tensioned Prestressed-Concrete Structure

## Technical Field of the Invention:

The present invention relates to a method of grouting an internal cable of a post-tensioned prestressed-concrete structure. More particularly, the present invention relates to a grouting method capable of surely and easily providing an internal cable completely filled with grout without an air trap remaining in the internal cable.

## Background Art:

In prestressed-concrete structures, e.g. bridges and overpasses, tendon corrosion and breaking accidents have occurred occasionally in recent years owing to the failure to satisfactorily fill grout into the internal cables of such prestressed-concrete structures.

The internal cable is buried in concrete in its entirety. Therefore, it has been difficult to inspect and confirm the filling (injected) condition of grout in the sheath of the internal cable and the condition of the cable after the grouting operation.

In the present state of the art, the grout filling condition is checked by a non-destructive inspection method, e.g. X-ray inspection, ultrasonic inspection, or

impact reflection wave inspection. However, it is difficult to completely grasp the condition of the grout in the sheath.

Under these circumstances, a grout material exhibiting favorable flowability and causing minimal bleeding has been developed. However, in the actual grouting operation, the grout material is pumped into the sheath. Therefore, air is entrapped into the grout material during the pumping operation as well as a material mixing operation performed when the grout material is prepared. The air is likely to collect in the sheath in the vicinity of an elevated portion at a bend in the internal cable or in the vicinity of an end of the internal cable, thus forming an air trap (void) unfavorably.

The grout material is injected to fill the space between the sheath inner wall and the prestressing steel. The grout material is a mixture of cement, water, and an admixture. It is demanded that the grout material should have the property of exhibiting excellent flowability and causing no segregation. However, cement and water are likely to separate in the sheath due to a difference in specific gravity before the grout material hardens. That is, the cement content settles downward, and the water content remains at the upper side (in the form of bleeding water). When the water evaporates, a void (air trap) may be formed and remain. External water entering the void over a long period of time will corrode the prestressing

steel. This may result in breaking of the prestressing steel.

Further, prestressing steel stranded wire is used as the cable material in most applications. Therefore, sieving action or capillary action is likely to occur between a plurality of strands constituting the stranded wire, causing water and cement to separate from each other.

Fig. 4 is an explanatory view illustrating the injection of grout into an internal cable. Fig. 5 is an explanatory view illustrating the formation of an air trap during the injection of grout into the internal cable. As shown in these figures, no void (air trap) V is formed in a case (A) where a grout material G flows through a sheath 3′ in such a manner as to travel upward from the lower side. However, in a case (B) where the grout material G flows through a downwardly bent portion of the sheath 3′ where the grout material G travels downward from the upper side, in particular, the leading end of the flow of the grout material G travels along the lower inner wall of the sheath 3′ while leaving a void V in the upper part of the bore of the sheath 3′ [see (a) of Fig. 5]. In a part of the sheath 3′ where the downwardly bent portion of the cable reaches its lower extremity, the grout material G fills the sheath 3′ over the entire area of the bore of the sheath 3′ [see (b) of Fig. 5]. Thereafter, the grout material G travels backward to rise in the sloped portion of the sheath 3′ [see (c) of Fig. 5].

The void V in the leading end of the flow of the

grout material G decreases gradually while the grout material G is traveling backward because the trapped air is discharged through discharge pipes 8a and 8b (see Fig. 4), which are generally provided in the vicinity of the top of the upwardly bent portion of the sheath 3'. Whether the air trap V disappears or remains depends on the installation position of the discharge pipes 8a and 8b and the number, bore diameter, height, etc. of the pipes 8a and 8b.

Disclosure of Invention:

Accordingly, the present invention provides a grouting method capable of surely and easily providing an internal cable of a post-tensioned prestressed-concrete structure that is completely filled with grout without an air trap remaining in the internal cable.

That is, the present invention provides a method of grouting an internal cable of a post-tensioned prestressed-concrete structure as follows:

(1) A method of grouting an internal cable of a post-tensioned prestressed-concrete structure, which is characterized by fabricating a cable for testing at a place other than a construction site of the post-tensioned prestressed-concrete structure. The cable for testing has a sheath made of a transparent material and has the same three-dimensional configuration as that of the internal cable at the construction site except that the cable for testing does not have a cast concrete part. Prior to

carrying out an operation of grouting the internal cable of the post-tensioned prestressed-concrete structure at the construction site, grouting testing is performed by injecting grout into the cable for testing under a plurality of different testing conditions. The best grouting conditions are selected from grouting testing results obtained by visual observation through the transparent sheath. The selected best grouting conditions are applied to grouting actually carried out at the construction site.

(2) A method of grouting an internal cable of a post-tensioned prestressed-concrete structure, which is characterized by fabricating a cable for testing as a partial specimen at a place other than a construction site of the post-tensioned prestressed-concrete structure. The cable for testing has a sheath made of a transparent material and has the same three-dimensional configuration as that of a lengthwise part of the internal cable at the construction site in which an air trap is likely to occur, except that the cable for testing does not have a cast concrete part. Prior to carrying out an operation of grouting the internal cable of the post-tensioned prestressed-concrete structure at the construction site, grouting testing is performed by injecting grout into the cable for testing under a plurality of different testing conditions. The best grouting conditions are selected from grouting testing results obtained by visual observation through the transparent sheath. The selected best grouting

conditions are applied to grouting actually carried out at the construction site.

(3) A method of grouting an internal cable of a post-tensioned prestressed-concrete structure as stated in the above paragraph (1) or (2), which is characterized in that the three-dimensional configuration of the cable for testing having a sheath made of a transparent material is formed by using supports.

(4) A method of grouting an internal cable of a post-tensioned prestressed-concrete structure as stated in any of the above paragraphs (1) to (3), which is characterized in that the cable for testing having a three-dimensional configuration has a transparent sheath provided only in the vicinity of a bent portion or/and in the vicinity of an elevated portion of the cable.

(5) A method of grouting an internal cable of a post-tensioned prestressed-concrete structure as stated in any of the above paragraphs (1) to (4), which is characterized in that the sheath made of a transparent material, which is used in grouting testing performed at a place other than the construction site, makes it possible to surely and easily perform, by visual observation, inspection of the grout filling condition during grouting, testing to find a portion in the sheath where an air trap is formed, selection of optimal conditions for regrouting an air-trap portion, and selection of positions where a grout discharge pipe and an air exhaust pipe are to be installed, and the number and bore diameter of such pipes.

(6) A method of grouting an internal cable of a post-tensioned prestressed-concrete structure as stated in any of the above paragraphs (1) to (5), which is characterized in that the testing conditions of the grouting testing are at least one selected from the following (1) to (6): (1) the composition of the grout, e.g. the mix proportions of components of the grout, or the water-cement ratio of the grout; (2) the physical properties of the grout, e.g. the viscosity-temperature characteristics and bleeding characteristics of the grout; (3) grouting means, e.g. grouting pressure, grouting speed, and grouting quantity; (4) regrouting means, e.g. the pressure, rate and quantity of grout reinjected through an injection pipe into a portion in the sheath where an air trap is formed, and the position, number and bore diameter of regrouting pipes; (5) grout discharge and air exhaust means, e.g. the installation position, number and bore diameter of grout discharge and air exhaust pipes; and (6) a step of the construction procedure, i.e. a step at which, prior to grouting, water is previously injected into the sheath, and as the grout is injected, the injected water is discharged from the sheath, thereby making the flow of the grout in the sheath even more uniform by utilizing a small difference in specific gravity between the grout and water, or a step of lowering the temperature of concrete and the temperature in the sheath when these temperatures are high.

(7) A method of grouting an internal cable of a

post-tensioned prestressed-concrete structure as stated in any of the above paragraphs (1) to (6), which is characterized in that the transparent sheath is made of a polyethylene resin.

(8) A method of grouting an internal cable of a post-tensioned prestressed-concrete structure as stated in any of the above paragraphs (1) to (7), which is characterized in that the transparent sheath is made of an ionomer resin.

Brief Description of the Drawings:

Fig. 1 is a schematic view of grouting testing equipment.

Fig. 2 is an explanatory view illustrating the injection of grout into a cable for preliminary testing.

Fig. 3 is an explanatory view illustrating another example of the grouting testing.

Fig. 4 is an explanatory view illustrating grouting.

Fig. 5 is an explanatory view illustrating the formation of an air trap during the injection of grout into an internal cable.

Explanation of Reference Signs:

1: testing equipment for grouting cable for preliminary testing

2: cable, 2′: internal cable

3: transparent sheath, 3′: sheath

4: end anchoring device (anchorage)

5: supports (pipe supports for scaffolding)

6: grouting pipe

7: regrouting pipe

7v: open-close valve for regrouting pipe

8 (8a, 8b, 8c): discharge pipe (exhaust pipe)

8av, 8bv: open-close valves for exhaust pipes

9: exhaust pipe

G: grout

V: air trap

Best Mode for Carrying Out the Invention:

An embodiment of the present invention will be described below with reference to the accompanying drawings.

In the present invention, prior to grouting an internal cable of a post-tensioned prestressed-concrete structure at a construction site, testing equipment 1 for grouting a cable for preliminary testing is assembled, as shown in Fig. 1, at a place near the construction site or at a place other than the construction site, e.g. in a factory, by using supports (pipe supports for scaffolding) 5. The testing equipment 1 has a cable 2 fabricated with the same (or approximately the same) three-dimensional configuration (i.e. cubic configuration) at that of the internal cable at the construction site. The cable 2 has a transparent sheath 3 that allows the grout filling condition therein to be checked by visual observation from the outside of the sheath 3.

The cable 2 of the testing equipment 1 has the same three-dimensional configuration as that of the internal cable at the construction site except that it does not have a concrete part that would otherwise be cast at the construction site. The cable 2 extends over a distance equal to the full length of the internal cable at the construction site. Testing is performed by injecting grout (G) into the transparent sheath 3 of the cable 2 from a grouting pipe 6.

The testing is performed under a plurality of different testing conditions. During the testing, the filling condition of grout (G) in the cable 2 is visually observed through the transparent sheath 3, and observation data is recorded.

Fig. 2 is an explanatory view illustrating the injection of grout into a cable for preliminary testing. Fig. 2 shows that when grout G is injected into a cable 2 in grouting testing, an air trap V is formed in an elevated portion of the cable 2. A regrouting pipe 7 and discharge (exhaust) pipes 8a and 8b are provided to stand in the vicinity of the elevated portion of the cable 2. A grouting pipe 6 and an exhaust pipe 9 are installed at an anchorage provided at the left end of the cable 2. A discharge pipe 8c is installed at another anchorage provided at the right end of the cable 2. It should be noted that open-close valves 7v, 8av and 8bv are attached to the respective upper ends of the pipes 7, 8a and 8b.

First, grout G is injected into the transparent

sheath 3 of the cable 2 from the grouting pipe 6 by using a pump (not shown) at a specific pressure, delivery speed and delivery time, for example, to determine and record respective numerical values of the pressure, delivery speed and delivery time at which all the trapped air is discharged through the discharge pipes 8a and 8c and hence the void V disappears.

Grouting testing is performed a plurality of times under different testing conditions, i.e. with regard to different kinds, temperatures, etc. of the grout G, thereby selecting and recording an optimal grout, an optimal grout temperature, etc.

From the grouting testing results thus obtained, the best grouting conditions are selected, and all or essential ones of the selected best grouting conditions are applied to grouting actually carried out at the construction site.

In general, factors in the formation of an air trap V during grouting the internal cable are as follows: (1) the kind of grout material; (2) equipment used for grouting; (3) the configuration of the cable; (4) the installation position and number of grouting and discharge pipes and the open-close timing of the pipes; (5) whether or not regrouting is carried out; (6) the relationship between the configuration of the anchorage and the installation position of the grouting and discharge pipes; (7) temperature conditions at the construction site; and (8) whether or not water is injected into the sheath prior

to grouting.

For example, detailed factors in the air-trap formation in terms of the kind of grout material as stated in the above (1) are the flowability, viscosity and non-segregating property of the grout material. Further, the air-trap formation is dependent on the water-cement ratio of the grout material, the cement particle size, the properties of the admixture, and the temperature of mixed grout that is determined by the atmospheric temperature and the temperature of the constituent materials.

Next, the equipment (not shown) used for grouting as stated in the above (2) may cause formation of an air trap. The air-trap formation is dependent on the blade structure and rotational speed of a mixer and the deliver pressure and discharge quantity of the pump.

Air-trap formation factors in terms of the configuration of the cable 2 as stated in the above (3) include the outer diameter, bore diameter and length of the sheath, irregularities on the outer peripheral surface of the sheath, and the three-dimensionally curved configuration of the cable throughout the full length thereof.

The installation position and number of grouting and discharge pipes as stated in the above (4) are dependent on the installation position and number of regrouting pipes 7 for secondary injection and the installation position and number of discharge pipes therefor. In addition, the air-trap formation is dependent on the bore

diameter and length (height) of the grouting and discharge pipes and the discharge pipe open-close timing during grouting and immediately after the completion of grouting.

In addition, the air-trap formation is dependent on whether or not regrouting is carried out as stated in the above (5), and the relationship between the configuration of the anchorage and the installation position of the grouting and discharge pipes as stated in the above (6). Further, the temperature conditions at the construction site, i.e. the atmospheric temperature and the concrete temperature, as stated in the above (7), affect significantly the flowability of the grout and are considered to be a factor in the air-trap formation.

Therefore, by taking into consideration the factors in the formation of an air trap V during grouting the cable 2, testing equipment 1 is assembled at a place other than the construction site by using supports (pipe supports for scaffolding) 5, as shown in Fig. 1, to grout a cable for testing having the same (or approximately the same) three-dimensional configuration (i.e. cubic configuration) as that of the internal cable at the construction site.

Thus, a cable 2 is fabricated that has the same three-dimensional configuration as that of the internal cable at the construction site except that it does not have a cast concrete part and the sheath is not black but transparent. The cable 2 may simulate either the full length or a part of the internal cable at the construction

site. It is also possible to use as a specimen a lengthwise part of the cable 2 where an air trap is likely to occur. Then, grouting testing is performed by injecting grout G into the sheath 3 made of a transparent material.

In consideration of the above-described factors in the formation of an air trap during grouting, testing is performed under a plurality of different testing conditions. During each testing process, the filling condition of the grout in the cable 2 is visually observed through the transparent sheath 3, and observation data is recorded.

By virtue of the use of a sheath made of a transparent material in grouting testing performed at a place other than the construction site, it is possible to surely and easily perform, by visual observation, inspection of the grout filling condition during grouting, testing to find a portion in the sheath where an air trap is formed, selection of optimal conditions for regrouting an air-trap portion, and selection of positions where a grout discharge pipe and an air exhaust pipe are to be installed, and the number and bore diameter of such pipes. Thus, the best grouting conditions can be selected.

It should be noted that if an air trap V is formed in the transparent sheath 3, an analysis and improvement are made on the basis of the above-described air-trap formation factors. Then, testing is performed again, and observation data is recorded.

The best grouting conditions are selected from the

data obtained by the above-described testing, and the selected best grouting conditions are applied to grouting actually carried out at the construction site.

Testing items (conditions) of the grouting testing are as follows: ① the composition of the grout, e.g. the mix proportions of components of the grout, or the water-cement ratio of the grout; ② the physical properties of the grout, e.g. the viscosity-temperature characteristics and bleeding characteristics of the grout; ③ grouting means, e.g. grouting pressure, grouting speed, and grouting quantity; ④ regrouting means, e.g. the pressure, rate and quantity of grout reinjected through an injection pipe into a portion in the sheath where an air trap is formed, and the position, number and bore diameter of regrouting pipes; ⑤ grout discharge and air exhaust means, e.g. the installation position, number and bore diameter of grout discharge and air exhaust pipes; and ⑥ a step of the construction procedure, i.e. a step at which, prior to grouting, water is previously injected into the sheath, and as the grout is injected, the injected water is discharged from the sheath, thereby making the flow of the grout in the sheath even more uniform by utilizing a small difference in specific gravity between the grout and water, or a step of lowering the temperature of concrete and the temperature in the sheath when these temperatures are high. At least one selected from the above ① to ⑥, preferably all of ① to ⑥, are used as testing items.

Fig. 3 is an explanatory view illustrating another

example of the grouting testing, in which a partial specimen is used as a cable for preliminary testing. Fig. 3(a) is a schematic view showing the full length of a cable for preliminary testing that has the same (or approximately the same) three-dimensional configuration (i.e. cubic configuration) as that of the internal cable at the construction site. Fig. 3(a) also shows a lengthwise part of the cable (surrounded by the dot-dash line in the figure) where an air trap is likely to occur. Fig. 3(b) is an enlarged detailed view illustrating a partial specimen of cable that comprises the lengthwise part where an air trap is likely to occur, which is surrounded by the dot-dash line in Fig. 3(a).

In this example, as shown in Fig. 3(b), a partial specimen is fabricated and laid, which has the same three-dimensional structure (i.e. cubic structure) as that of a lengthwise part of the internal cable at the construction site in which an air trap is likely to occur. Then, grout (G) is injected into the transparent sheath 3 of the cable 2 from the grouting pipe 6 under various conditions, and while visually checking the occurrence of an air trap, grout is reinjected from the regrouting pipe 7 under various conditions by opening and closing the open-close valve 7v at varied timing. Further, air or/and a part of the injected grout are discharged through the grout and air discharge pipes 8a and 8b by opening and closing the open-close valves 8av and 8bv at varied timing. In this way, the grouting testing is performed under various

conditions. It should be noted that reference numerals 8c and 9 in the figure denote exhaust pipes provided at both ends of the cable 2.

The results of the testing performed as stated above are recorded, and optimal conditions are selected from the testing results. The selected conditions are applied to the process of grouting the internal cable at the construction site.

This example is applied in a case where a place for testing as large as the construction site is unavailable. That is, a specimen comprising only an essential part of cable where an air trap is likely to occur is fabricated to perform testing. This example allows testing to be performed at reduced costs and in a reduced space and still permits the testing results to be applied favorably to the construction site.

It should be noted that the cable 2, which comprises either the full length of the three-dimensionally configured structure for testing or a lengthwise part thereof where an air trap is likely to occur, may have a transparent sheath provided only in the vicinity of a bent portion and in the vicinity of an elevated portion of the cable. In this case, the other portion of the cable 2 may be made of a black polyethylene or the like that is used at the construction site.

The grout material injected into the three-dimensionally configured structure for testing is preferably the same as that used at the construction site.

It is also possible to inject a colored grout material prepared by mixing a grout with a small amount of an inorganic coloring material, e.g. chromium oxide, iron oxide, copper oxide, or manganese oxide, or an organic coloring material. The use of a colored grout material allows the filling condition of the grout in the transparent sheath to be grasped even more clearly. It is preferable to adjust the degree of pigmentation so that the color of the grout material is not very deep but sufficiently light to allow an air trap to be readily found.

Examples of materials for the transparent sheath are a polyethylene resin, a vinyl chloride resin, a polypropylene resin, a polycarbonate resin, and a Teflon resin. It is particularly preferable to use a material consisting essentially of a polyethylene-based ionomer resin, in which the ionomer resin is an α-olefin-α, β-unsaturated carboxylic acid copolymer having carboxyl groups neutralized with metal ions.

It is also preferable to use a material consisting essentially of an ionomer resin that is a binary copolymer of α-olefin and α, β-unsaturated carboxylic acid, in which the copolymer contains from 5 to 20% by weight of α, β-unsaturated carboxylic acid, and the degree of neutralization achieved by the metal ions is from 10 to 90 mol % with respect to the acid group.

Further, it is preferable that the transparent sheath should be formed from either one material selected

from those stated above or a composite material consisting essentially of two or more materials selected from those stated above, and the configuration of the sheath should be the same as that of the sheath actually used at the construction site.

It should be noted that the term "transparent" in the term "transparent sheath" as used in the present invention means, for example, that the filling condition of a grout material being filled into the sheath can be visually observed from the outside of the sheath. It is possible to use a sheath having any property as long as it performs the above-described function. The term "transparent sheath" may mean a sheath having light transmission properties, for example. Light in this case may mean visible light. The term "sheath" means a hollow, typically tubular, member that can pass prestressing steel in the hollow portion thereof. The sheath performs the function of sheathing the prestressing steel extending through the hollow portion.

Industrial Applicability:

With the conventional method, whether or not the sheath is satisfactorily filled with grout without an air trap remaining therein cannot be checked even if influential factors are examined from various angles and the best efforts are made because at the construction site the internal cable is laid in concrete and hence the sheath is hidden by the concrete. Therefore, it cannot be

known whether the internal cable has completely been filled with grout or the resulting internal cable has the danger of corrosion or breaking because of insufficient filling of grout. Thus, anxiety and danger are involved in the conventional method.

According to the present invention, however, grouting testing is performed by using a cable for preliminary testing that is installed at a place other than the construction site by using a transparent sheath. The cable for preliminary testing may have the same configuration as that of the internal cable at the construction site throughout the full length thereof. Alternatively, the cable for preliminary testing may be a partial specimen having the same configuration as that of a lengthwise part of the actual internal cable where an air trap is likely to occur. By virtue of the grouting testing, it is possible to check, before the actual grouting process, not only the filling condition of grout being filled into the sheath but also the grout filling condition after the completion of the filling and also after the grout has hardened, and optimal grouting conditions can be selected. Therefore, during grouting performed at the construction site thereafter, no air trap is formed in the sheath, and an excellent post-tensioned prestressed-concrete structure can be provided.